Nevada Water Resources Research Institute
Annual Technical Report
FY 2012

Introduction

Research Program Introduction

None.

Measuring Water Use of Tamarisk and Impacts from Biocontrol: Lower Virgin River, NV

Basic Information

Title:	Measuring Water Use of Tamarisk and Impacts from Biocontrol: Lower Virgin River, NV
Project Number:	2011NV178B
Start Date:	3/1/2011
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	NV03
Research Category:	Climate and Hydrologic Processes
Focus Category:	Acid Deposition, Ecology, Water Quantity
Descriptors:	Tamarisk, Virgin River, Water
Principal Investigators:	Kumud Acharya

Publications

1. Conrad, B., Acharya, K., Dudley, T., and Bean, D. (2013) Episodic herbivory by the tamarisk beetle in Tamarix ramosissima increases leaf litter nitrogen and stem starch content: a short communication. Journal of Arid Environments 94, 76-79.
2. Sueki, S., Acharya, K., Healey, J., and Jasoni, R. (2013) Defoliation effect of Diorhabda carinulata on evapotranspiration from Tamarix in the Lower Virgin River: Are Beetles Saving Water? 2013 Universities Council on Water Resources / National Institutes for Water Resources Annual Conference, Lake Tahoe, CA. June 11 to 13, 2013.

Annual Progress Report

Title: **Measuring Water Use of Tamarisk and Impacts from Biocontrol: Lower Virgin River, NV**

PI: Kumud Acharya, DRI
Co-PIs: Sachiko Sueki and John Healey, DRI

Problem and Research Objectives

The lower Virgin River is a tributary of the Colorado River System and considered a major component of the water budget of the Southwest. The Virgin River flows through the Tri-State area of Arizona, Utah, and Nevada with a mean flow rate of 100 cubic feet per second. The State of Nevada contains 53% of the drainage basin followed by equal shares to Arizona and Utah at 24%. The river's relevance to each state is an important issue as rising population growth results in greater demands on a depleting, limited water supply. To compound the situation, an avaricious water-consuming plant has inundated this region reducing water availability. The invasion of non-native plant species, *Tamarix* (tamarisk, salt cedar), along the lower Virgin River and other river systems has developed riparian communities of mono-specific thickets. In addition to detrimental effects on biodiversity along these corridors, tamarisk commonly occurs in dense thickets that result in high evapotranspiration (ET) rates commonly emanating from relatively shallow groundwater. Extraction of groundwater can reduce stream flow, increase the salinity of soils and vadose zones, thus potentially degrading water quality for irrigation and other potable uses. Traditional eradication efforts such as herbicidal treatment, fire and mechanical removal have either proven too costly or have negative impacts on the native flora which they are intending to restore. Recently, new eradication efforts have shifted towards the use of a biocontrol agent, the saltcedar leaf beetle (*Diorhabda carinulata*). The beetle was introduced to reduce tamarisk leaf cover along many western water sheds. Defoliation of tamarisk in lieu of *Diorhabda carinulata* infestation has been occurring along the Colorado River and its tributaries since the release of the beetle in 2001.Recently, the establishment of large beetle populations in Lower Virgin River have been evident and known to extend south into the Overton arm region of the Lake Mead in 2011. The rapid progression of these beetles down the Colorado River basin provides a unique opportunity to directly assess the beetle's defoliation of tamarisk as a water savings measure. These savings can be accessed by measuring the change in ET while the beetles are actively migrating through tamarisk groves. The primary goal of the research is to quantify ET prior to and following episodic herbivory by the leaf beetle, calculate the difference between ET of those times and estimate to a net water savings of along the Virgin River. Other data collection efforts are the monitoring stream flow and daily groundwater oscillations from groundwater wells.

Observation wells are maintained by Desert Research Institute, Southern Nevada Water Authority, and Virgin Valley Water District. Additionally impacts of beetles' defoliation on tamarisk physiology and ecology are also being studied by measuring leaf litter nitrogen (N), stem starch contents and pre- and post-defoliation temperatures in a tamarisk stand.

Methodology

The study has focused primarily on a research site established by funding from the U.S. Bureau of Reclamation (Technical Services Center, Denver) along the alluvial-filled valley of the lower Virgin River and other supplemental field data. The site consists of a groundwater monitoring well and the equipment necessary to utilize the classic Eddy Covariance technique to determine atmospheric fluxes and to obtain accurate estimates of ET. Eddy Covariance set-up includes: 1) a 3D sonic anemometer (model CSAT3) mounted one meter above the canopy, 2) an open-path infrared gas analyzer (model CS7500) mounted one meter above the canopy, 3) a REBS net radiometer (model Q7.1), 4) two soil heat flux plates (model HFP01SC), 5) two soil thermocouple probes (model TCAV-L), 6) two soil water reflectometers (model CS616), and 7) air temperature/relative humidity probe (model HMP45C-L).

Data is stored on a datalogger (Campbell Scientific CR5000) equipped with a 2 Gb memory card. Data is monthly collected during site visits where "swapping" the full memory card with an empty one occurs. Additionally, real-time data is checked with a lap-top PC to ensure appropriate sensor operation. Fluxes are later calculated off-line and corrected using EddyPro (LI-COR Inc.). This technique is used on all data and allows for the following corrections: 1) despiking and low pass filtering, 2) sonic temperature path correction, 3) sonic flow distortion, 4) rotating velocity signals, 5) sonic temperature density correction, 6) highpass filtering signals, 7) frequency response corrections, 8) sonic temperature correction and 9) density corrections. All corrections are made to the 10-Hz time series data (time interval of 0.1 second) prior to calculating 30-minute averages. Fluxes are then calculated using the averaged data. The groundwater monitoring well is used to record diurnal groundwater fluctuations on 30-minute averages and utilizes a pressure transducer installed in a shallow piezometer (5.08 cm diameter). Data from the transducer is downloaded to a computer during each site visit.

Physiological effect of beetles' defoliation was studied by collecting stem and foliage at five sites representing a chronosequence in years since initial beetle establishment and defoliation (Table 1). Stem and foliage collections occurred in early January of 2011, when Tamarix plants were inactive during their deciduous winter phase. Litter samples from all locations except Dolores (samples were not available at the time of analysis due to a delay in sampling at that site) were analyzed for N using a Perkin

Elmer CHN analyzer (Perkin Elmer Inc., San Jose, CA, USA). Finely ground stem samples from all sites were analyzed for starch content using the enzymatic method.

Temperature loggers, iButtons, mainly to monitor temperature changes in response to herbivory were placed in a monoculuture of mature tamarisk stand on the upstream of the Riverside Road Bridge Virgin River, Mesquite. iButtons were also placed on tamarisks outside of tamarisk stand as controls.

Table 1. Site location and herbivory classification for stem and leaf litter collection.

Site	Classification	Location	Herbivory Histroy
Meadowland’s farm	Control	36°41’54.23”N, 114°15’27.46”W	No defoliation
Riverside Bridge	Low	36°44’00.23”N, 114°13’08.12”W	1st defoliation end of 2010
Big Bend	Low	36°50’20.63”N, 113°59’11.35”W	1st defoliation 2010
School Bus	Intermediate	36°54’36.16”N, 113°53’45.36”W	1st defoliation 2009
St. George River Rd. UT	High	37°05’12.44”N, 113°33’21.59”W	3+ yrs of defoliation
Dolores River, UT	High	38°44’37.76”N, 109°07’55.48”W	4+ yrs of defoliation

Principle Findings and Significance

This project continues data collection from previously funded project (see above). The previous project ended in spring 2011 and the current project started immediately after that. To compare ET difference before and after arrival of the beetles, the base-line data was collected in 2010 under the initial project will be pre-beetle times as the beetles arrived at the field site in the summer of 2011.

The difference between data collected in 2010 and 2011 showed that defoliation caused by beetles’ herbivory reduced the ET rates resulting in less phreatophytic ground water consumption. The beetles had migrated into the Eddy covariance site and began their defoliation of tamarisks in June 2011. Figure 1 shows daily ET over entire year of 2010 (before beetles’ arrival) and 2011 (after beetles’ arrival). Daily ET in 2011 substantially reduced by the beginning of July and gradually increased to the almost similar or slightly higher level than 2010 by September illustrating that the tamarisks recovered from the defoliation.

Figure 2 shows the comparison of ground water level over the time period of June to September during 2010 and 2011. The smaller oscillations imprinted on the larger oscillations represent diurnal fluctuations in the water table due to phreatophytic groundwater consumption. Peaks and valleys roughly correspond to daily times of 0600 and 1600 hours, respectively (clearly visible in Figure 3 of a week-long time frame). The plot from the beginning of July to August of 2011 clearly shows the reduced magnitude (dampening) of the diurnal fluctuations and the magnitude returned to the same level as 2010 by September. The period of nearly non-existent diurnal fluctuations in the water level data corresponds to the period of reduced ET.

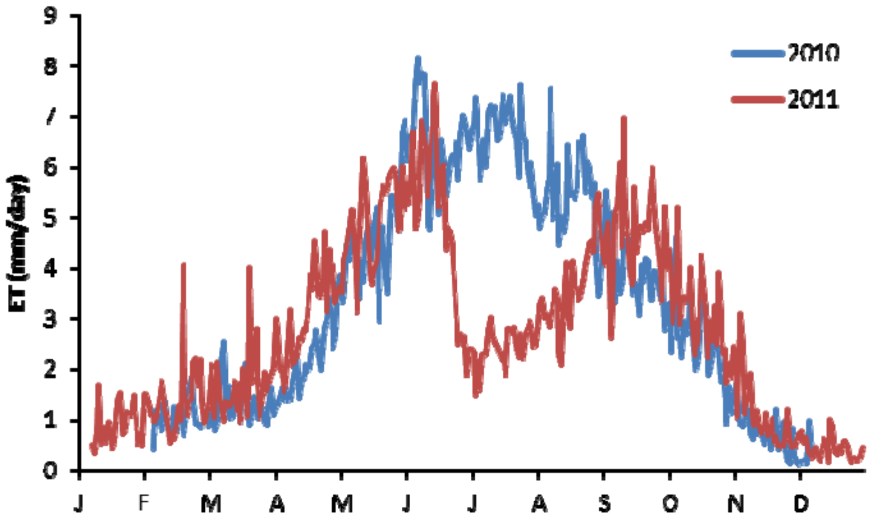

Figure 1. Daily ET of 2010 (before beetles' arrival) and 2011 (after beetles' arrival).

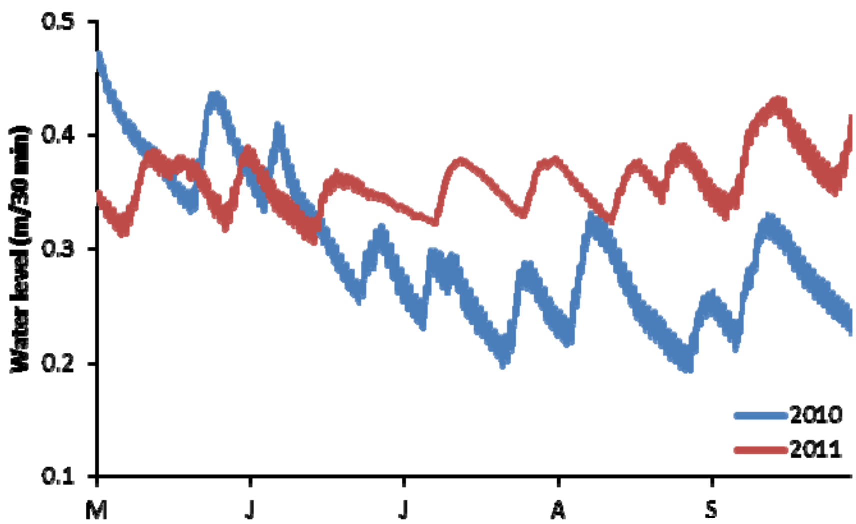

Figure 2. Water level from June to September in 2010 and 2011.

Figure 4 shows the monthly average of the differences in the magnitude of the diurnal fluctuations from June to September. This figure also supports the diurnal fluctuations patterns caused by beetles' defoliation. When there was no defoliation in 2010, the diurnal fluctuations of ground water and ET increased as ambient temperature increased. On the other hand, when beetles defoliated the tamarisks in the summer of 2011, the magnitude of diurnal fluctuations of ground water and ET were reduced while the average monthly temperature was at the peak. Monthly averaged temperatures in 2010 and 2011 are shown in Figure 5.

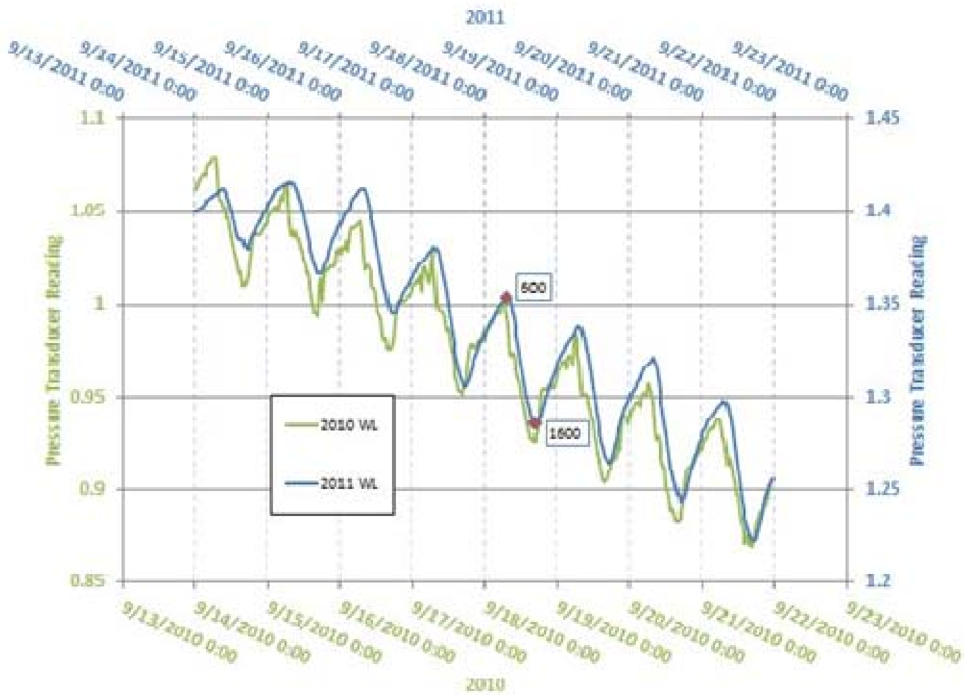

Figure 3. One-week water level record demonstrating similar magnitude of diurnal fluctuations pre and post defoliation and subsequent new growth.

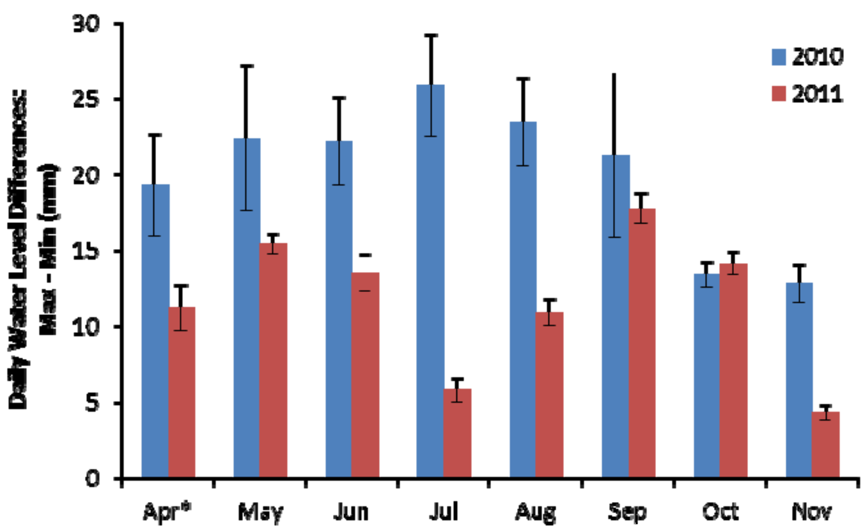

Figure 4. The monthly average of the differences in the magnitude of the diurnal fluctuations from April to September. Note that April data starts from the 21st of April.

Figure 3 shows diurnal fluctuations of the water table at the Virgin River site for one week period in September 2010 and 2011. The magnitude of the fluctuations is very similar from year to year over the same period. This implies that tamarisk recovered from the defoliation caused by the beetles and resumed their normal pattern of water

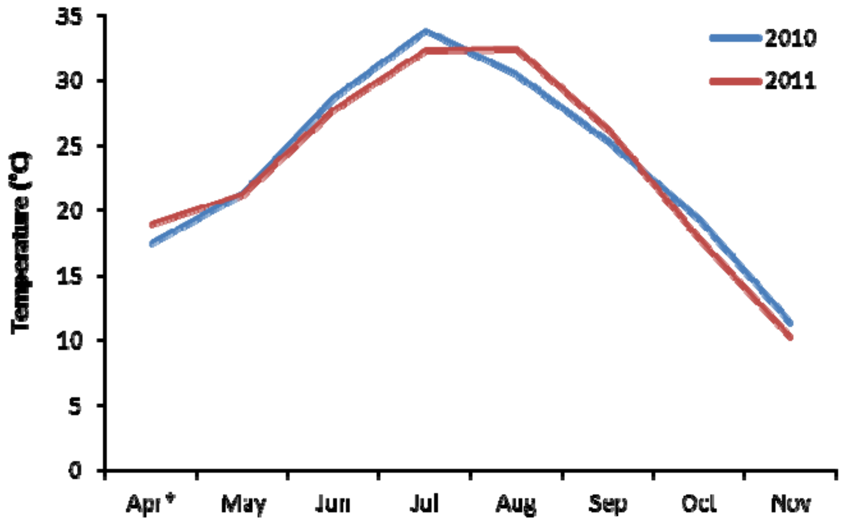

Figure 5. Monthly average temperature in 2010 and 2011. Note that April data starts from the 21st of April.

consumption as seen by the recurrence of diurnal fluctuations common to areas of active plant growth.

Table 2 shows leaf litter nitrogen and stem starch contents of un-affected and beetle-affected tamarisks. Plants that had not experienced herbivory by the beetle displayed significantly lower quantities of both litter nitrogen and stem starch than beetle-affected tamarisk trees. However, there were no significant differences in these two parameters among beetle-affected sites representing a chronosequence of defoliation history. Higher levels of nitrogen in leaf litter from beetle-affected trees may be a result of herbivory-induced desiccation and foliar mortality prior to the translocation of nitrogen back into plant reserves. Additionally, higher stem starch may be a result of either phloem damage reducing the translocation of photoassimilates, or an increase in the shunting of carbohydrates to the site of new leaf growth. Finally, the lack of correlation between years of herbivory and both leaf litter nitrogen and stem starch may indicate that as of yet there have not been sufficient defoliation events to yield anticipated host plant impact.

Table 2. Leaf litter nitrogen and stem starch content in control and beetle-affected sites

Site	N leaf litter %		Stem starch (mg/ml)	
Control	0.85 ± 0.05		40.8 ± 6.7	
Riverside	1.78 ± 0.08	*	64.8 ± 3.7	*
Big Bend	2.00 ± 0.16	*	67.0 ± 7.0	*
School Bus	1.63 ± 0.15	*	64.3 ± 4.4	**
St. George	1.63 ± 0.08	*	68.5 ± 5.3	**
Dolores	X		69.8 ± 4.0	**

Note: Asterisks indicate ANOVA; $p < 0.05$* and $p < 0.01$**

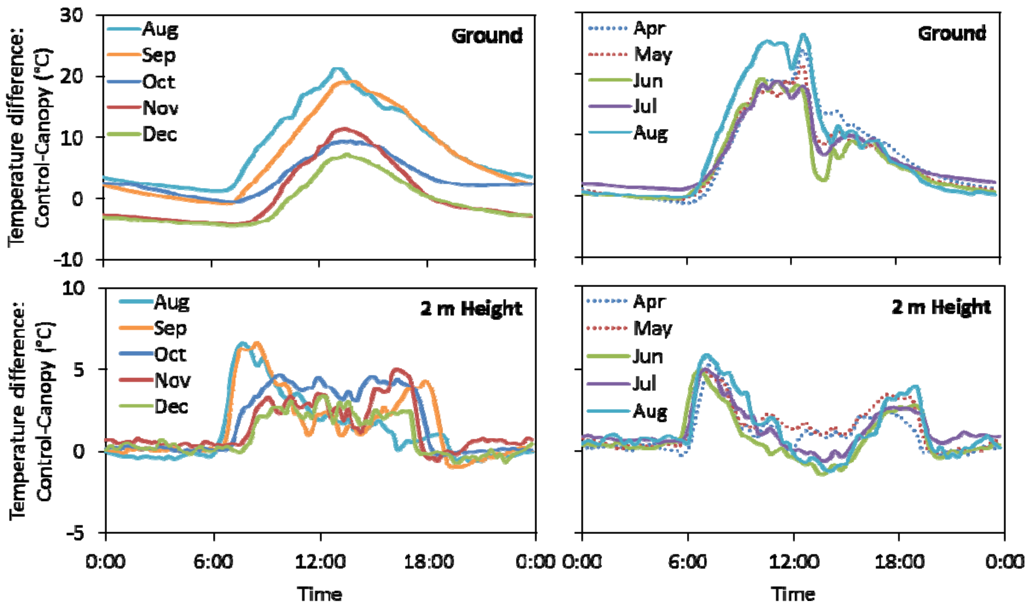

Figure 6. Differences between temperatures measured outside (control) and inside the canopy. Left and right figures are the results from 2010 and 2011, respectively.

Figure 6 showed monthly average temperature difference between outside (control) and inside tamarisk canopy. Temperatures were measured at ground (top figures) and at 2m height (bottom figures). The beetles arrived at the site at the end of August, 2010 but went into diapause almost immediately without causing any defoliation. Hence the data collected in 2010 was treated was pre-defoliation condition and used to compare with defoliated temperatures collected in 2011. There was hardly any noticeable difference between the temperatures. In general, temperatures inside the canopy were cooler than outside and that difference was more pronounced in the morning and evening than midday at 2m height. The difference on the ground temperatures was the highest during afternoon. In contrast, ground temperatures were higher inside canopy compared to bare ground (control) during months of November and December. This is probably due to wind effect outside of canopy. Heat is more easily diffused from the ground to the air when there is no tamarisk leading to cooler ground temperature.

Summary and Further Work

We are currently in the process of analyzing our data while continuing to collect additional data. Data collection is expected to continue for 2013 summer and fall. We plan to complete analysis of all the results after all the data are collected and finalize manuscripts at the end of 2013.

Information Transfer Activities

Results will be presented in upcoming Universities Council on Water Resources / National Institutes for Water Resources Annual Conference held at Lake Tahoe, CA in June 11 to 13, 2013.

Student/other Support

The project currently provides partial support to a postdoctoral researcher (Sachiko Sueki) for data analysis and an Assistant Research Scientist (John Healey) for field data collection. The project partially supported a graduate student, Mahesh Bhattarai.

Publications

Conrad, B., Acharya, K., Dudley, T., and Bean, D. (2013) Episodic herbivory by the tamarisk beetle in *Tamarix ramosissima* increases leaf litter nitrogen and stem starch content: a short communication. *Journal of Arid Environments* 94, 76-79.

Sueki, S., Acharya, K., Healey, J., and Jasoni, R. (2013) Defoliation effect of *Diorhabda carinulata* on evapotranspiration from *Tamarix* in the Lower Virgin River: Are Beetles Saving Water? 2013 Universities Council on Water Resources / National Institutes for Water Resources Annual Conference, Lake Tahoe, CA. June 11 to 13, 2013.

Assessment of Resiliency of Las Vegas Water System Under Climatic and Non-Climatic Stressors

Basic Information

Title:	Assessment of Resiliency of Las Vegas Water System Under Climatic and Non-Climatic Stressors
Project Number:	2011NV179B
Start Date:	3/1/2011
End Date:	2/28/2013
Funding Source:	104B
Congressional District:	NV03
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Use, Water Supply, Management and Planning
Descriptors:	Water Demand, Climate Change,
Principal Investigators:	Kumud Acharya, Kumud Acharya

Publications

There are no publications.

Annual Progress Report

Title: **Assessment of resiliency of Las Vegas water system under climatic and non-climatic stressors**

PIs: Mahesh R. Gautam and Kumud Acharya, DRI
Graduate Students: Srijana Dawadi and Peng Jiang, University of Nevada Las Vegas

Problem and Research Objectives

Until recently the Las Vegas Metropolitan represented one of the highest growing regions in the U.S. The Las Vegas Valley (LVV) obtains 90% of its water supply from the Colorado River while remaining 10% is from ground water. Residential water demand accounts for the highest water use in this region (SNWA, 2008), and although semi-arid in climatic setting, the LVV has among highest water consumption per capita in the southwestern United States. Recent frequent droughts and possibility of cutback due to climate change on water supply from the Colorado River have raised importance of demand side management (DSM). Implementation of demand side management measures can act as a new source of water.

Demand management has been practiced extensively in the LVV for the last decade. Water conservation efforts have reduced consumption from 1191 liters per capita per day (lpcd) in 2000 to 930 lpcd in 2010 (SNWA, 2009) despite increase in population, as shown in Figure 1. Still, Las Vegas has the highest per capita consumption compared to Tucson, and Albuquerque, the cities with similar climate. This leaves potential for further conservation of water in the LVV.

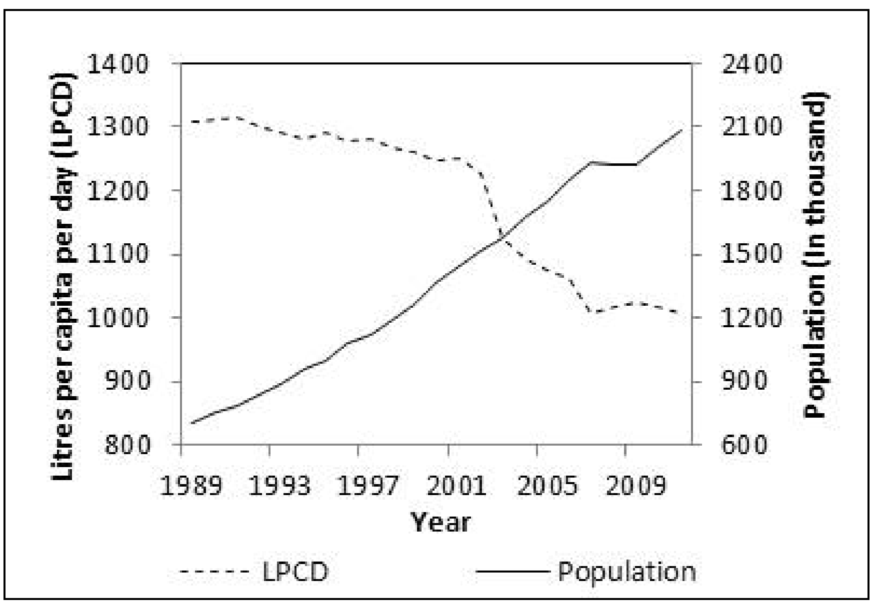

Figure 1. Water Consumption and population growth in the Las Vegas Valley from 1989 to 2010

With this motivation, this project analyzes the effect of population growth and changing climatic conditions on water demand in the LVV. In particular, the project aims to assess role of demand management, analyze portfolio of available water sources and vulnerability of the water supply system in the LVV. For this, the current study assesses potential of demand management of each city (within LVV) in detail by making use of available conservation and water demand data from various local agencies and contribute towards analyzing potential imbalances in demand and supply under population growth and climate change impact. A system dynamics model is being developed and applied to test various management strategies related to water conservation. The study will help develop local expertise, increase agency-academia interaction, and support students and young researchers. Results from the study will be published in peer reviewed journals and communicated to local stakeholders including general public. A major emphasis of the study is to contribute towards public education on the importance of water conservation through findings of the study. Additionally, data and results of the present study will be used to develop competitive proposals to further enhance our understanding in other critical areas of water management under climate change.

Methodology

As part of understanding demand and supply imbalances, first a system dynamics model (SD) model for water demand prediction was developed using STELLA software. System dynamics is a dynamic simulation model created by the causal influence of feedback loops and time delays. The user friendly interface of the system dynamics software is considered to be conducive to communication with stakeholders. Above all, understanding and dynamically simulating the changing behavior of water resources system can provide scientific basis for developing demand management strategies.

Water demand sector in the SD model was developed for residential customers in three different cities: the City of Las Vegas and Unincorporated areas in the Clark County, the City of Henderson, and the City of North Las Vegas. End use method was used for projecting water demand in all three cities. Indoor and outdoor demands were modeled separately. Water savings obtained with each appliance was estimated by subtracting the efficient use by water smart appliances from non-efficient use by non-conserving appliances. Outdoor water use was divided into landscape water use and water use by swimming pools. Landscape consists of both turf land and water smart landscape.

The landscape water demand was calculated by multiplying the average lawn size per household and water used per square meter for lawn irrigation. Water savings was obtained by converting turf grass into water smart landscape. Swimming pools water demand was calculated by multiplying the average pool area and depth with the water required per unit volume along with the water lost from uncovered pools due to evaporation. The frequency of water change in swimming pools was considered once a year. Use of cover in swimming pool is considered to save water loss due to evaporation. Likewise, pool cover saves on average about 2034 liters per square meters of water per year which would otherwise be lost (SNWA, 2009).

The effect of climate change was incorporated in the model by using ordinary least square regression equation obtained between monthly water demand, and climate variables including monthly average temperature and precipitation. The effect of change in both climate variables (temperature and precipitation) was considered. Temperature positively correlates the outdoor water demand, while precipitation is expected to negatively correlate.

Principle Findings and Significance

The study is currently ongoing due to a late start (delay in funding) and only a completed part is reported in this report.

Effectiveness of DSM measures

Turf conversion to water smart landscape started in year 1996 and progressed through years until today. Irrigation clock rebate started in year 1998 and ended in 2006.

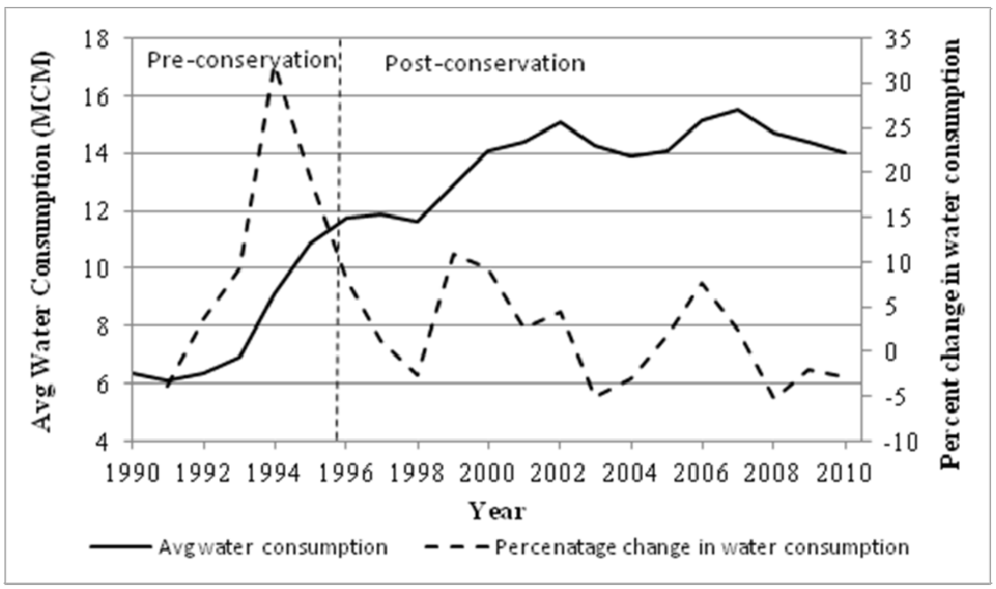

Figure 2. Average monthly water consumption and percentage change in water consumption in the Las Vegas Valley Water District

Effectiveness of DSM measures in the LVV can be clearly seen from the Figure 2, which shows the average single family residential water consumption from years 1990 to 2010; this duration is divided into pre- and post conservation period. Pre-conservation years start from 1990 and lasts till 1995, while post conservation runs from 1996 to 2010.

Water Demand Assessment

A city-wide spatial water demand has been successfully calibrated with calibration runs from 2003 to 2010. The calibrated model is used to run future simulations from 2013 to 2035. Future simulations are run for different scenarios of population growth and different demand side management measures. Two scenarios of population growth considered in the study are, (1) status quo population growth, and (2) only 50% of the projected growth. In status quo population growth scenario, it considered to increase in consistent with the growth rate projected by the Center for Business and Economic Research (CBER), and no further conservation potential was considered. Second scenario of population growth considers that the growth rate is only 50% of the rate projected by the CBER. This is consistent with recent reduction in the population growth rate in the LVV. Conservation scenario considered that houses built after 2013 will be built as water smart and will conserve water both indoor and outdoor.

Calibration of historic water usage for single family residential (SFR) customers was made for the city of Las Vegas from 2003 to 2010 based on observed water usage obtained from the Las Vegas Valley Water District (Figure 3). Root Mean Square Error (RMSE) and mean absolute error (MAE) of about 1.5 Million Cubic Meters (MCM) and 1.2 MCM were obtained between observed and simulated water demand for SFR customers. Because of lack of data availability and other problems in actual historical water usage for North Las Vegas and Henderson, we used an average percentage of water usage in the LVV to derive monthly water usage time series for these two cities. Figure 4 and 5 respectively show a comparison of simulated and observed monthly water usage data for North Las Vegas and Henderson for the duration of 2003 to 2010. RMS error between observed and simulated water demand in in North Las Vegas and Henderson was 0.44 MCM and 0.27 MCM, respectively. Similarly, MAE for Henderson and North Las Vegas were 0.21 MCM and 0.37 MCM, respectively.

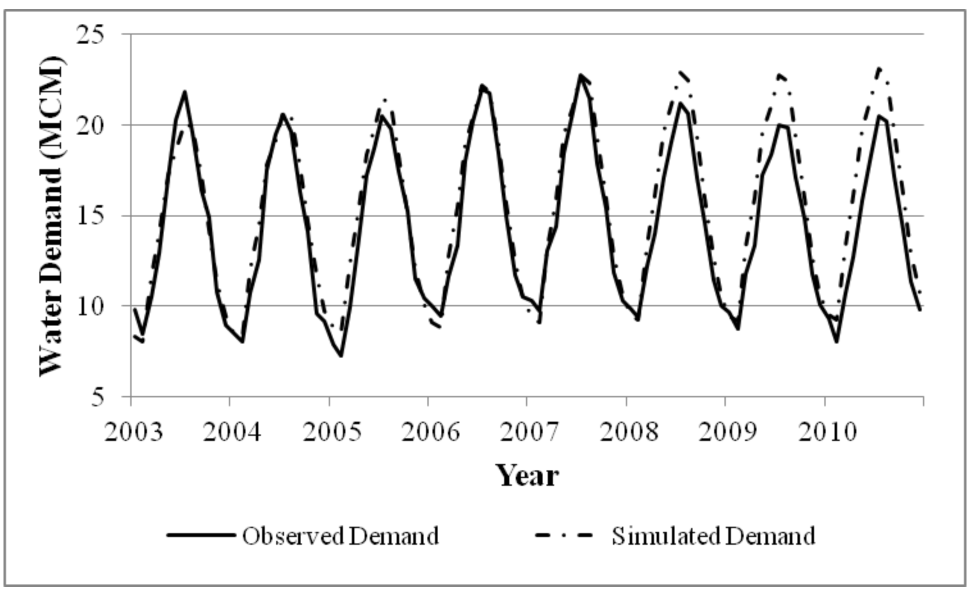

Figure 3. Comparison of historical and simulated water demand in the City of Las Vegas for duration of 2003 to 2010

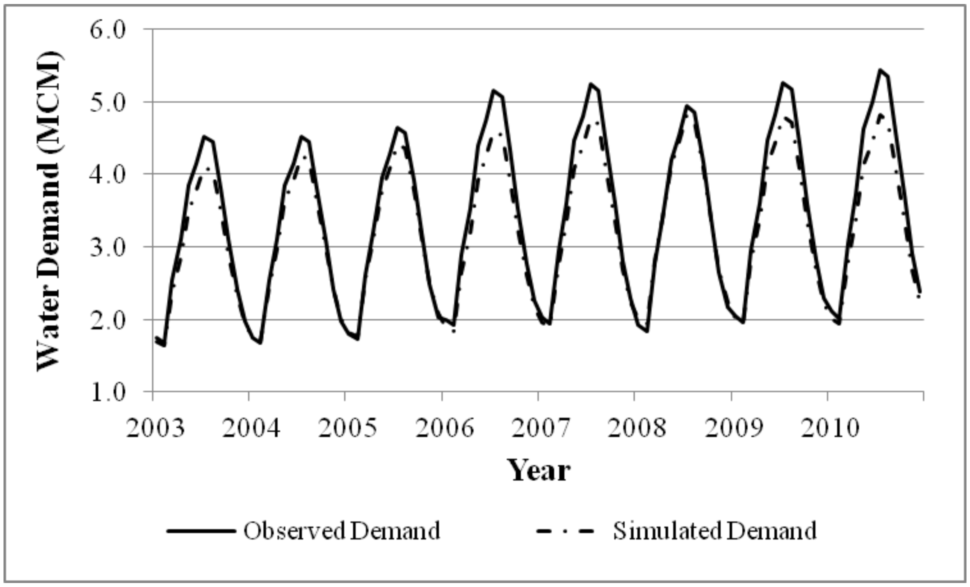

Figure 4. Comparison of historical and simulated water demand in the City of Henderson for duration of 2003 to 2010

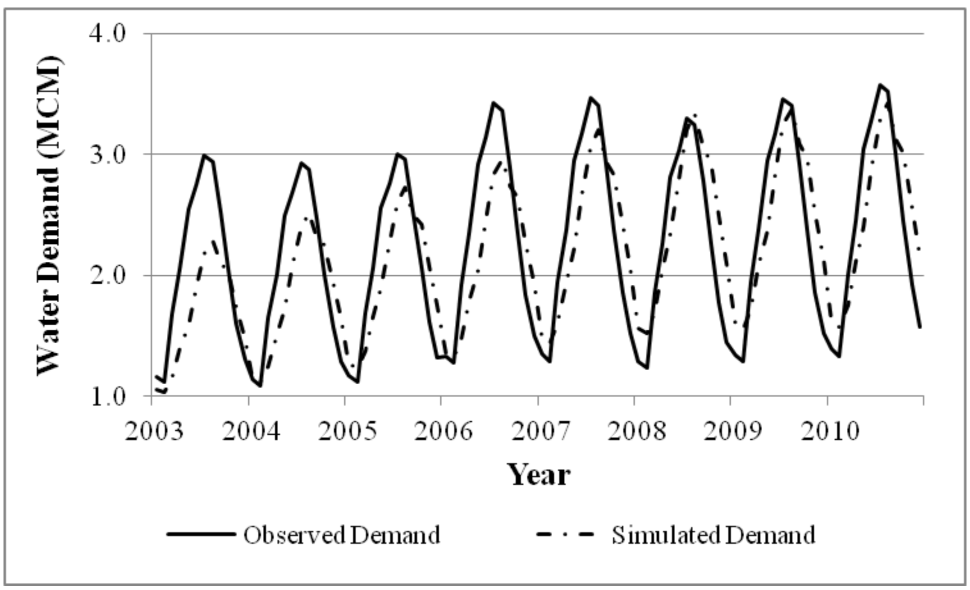

Figure 5. Comparison of historical and simulated water demand in the City of North Las Vegas for duration of 2003 to 2010

Simulation under two growth scenarios

The SD model was run for future simulation for the duration of 2013 to 2035. As described in the modeling approach, future simulations were run for different scenarios of population growth and water conservation measures, as well as climatic conditions (ongoing). For future simulations, results are presented for all residential customers in the LVV. Results for different scenarios are listed below:

a. Base case: In this scenario, population in each city grows as predicted by the CBER, and no further DSM measures are considered for water conservation; similarly there is no change in the climatic conditions. Water demand for residential customers in the cities of Las Vegas, North Las Vegas, and Henderson reached 390.4 MCM, 104.6 MCM, and 88.9 MCM respectively, a total of 583.9 MCM for residential customers in the LVV.
b. Conservation scenario: In conservation scenario, three DSM measures were considered: indoor conservation, landscape conversion, and using swimming pool covers. Each scenario was used with base case population growth rate and only 50% of the population growth. Additionally, retrofitting 50% of the existing houses were also considered. A list of all conservation policies for base case population growth scenario and only 50% of the projected growth scenarios are presented in the Table 1. Water demand in 2035 for all three cities is shown along with percentage savings for each DSM measure. Percentage savings were obtained by comparing water demand data obtained in conservation scenario with that obtained in base case scenario.

Principle Findings

Our simulation results showed that landscape conversion was found to be more effective compared to indoor conversion. Indoor conservation has not been extensively practiced in any of these three cities as credit is obtained with more water used indoor, through return flow credit policy. Total percentage savings for indoor conservation, landscape conversion, and combination of all DSM measures were 4.4%, 13.3%, and 17.8%, respectively. Similarly, water demand in 2035 for all the cities for different population growth rates and different DSM measures along with 50% retrofit of the existing houses are shown in the Table 1. With 50% growth in population from the projected growth rate, combination of DSM measure resulted in water demand of 278.4 MCM, 63.4 MCM, and 58.7 MCM in city of Las Vegas, North Las Vegas, and Henderson, respectively.

<u>Collaboration with Stakeholders and Research Result Dissemination</u>

The project was conducted with support from and collaboration with the Southern Nevada Water Authority (SNWA). Due to late start of the project, this research is still continuing and the results have yet to be presented to a workshop or symposium. However, series of presentations are aimed in the future at various local and regional conferences this year. The PIs, staff and the graduate student plan to attend AGU fall meeting and present a poster. A manuscript is currently being written for potential submission to a peer reviewed journal.

<u>Student Support</u>

The project partially supported a post-doctoral researcher and two graduate students (Peng Jiang from the Department of Geoscience, and Srijana Dawadi from the

Department of Civil and Environmental Engineering, University of Nevada Las Vegas). The project will contribute to a thesis chapter of Peng Jiang's Ph.D. dissertation.

<u>Publications</u>

A manuscript has been submitted to a peer reviewed journal paper and currently under review.

Table 1. Water demand in 2035 using different demand side management measures

S.N	DSM Measures	Water Demand (MCM)				% Savings
		Las Vegas	North Las Vegas	Henderson	Total	
Base Case Population Growth						
1	Indoor conservation	376.4	96.8	84.9	558.1	4.4
2	Landscape conversion	350.8	80.9	74.4	506.1	13.3
3	Combination	336.7	73.0	70.4	480.1	17.8
Base Case Population Growth With 50% Retrofit						
4	Indoor conservation	365.6	95.0	83.0	543.5	6.9
5	Landscape conversion	303.3	73.1	64.6	441.1	24.5
6	Combination	278.4	63.4	58.7	400.5	31.4
Population growth only 50% of the projected growth						
7	Indoor conservation	317.2	68.1	68.4	453.8	22.3
8	Landscape conversion	309.7	61.6	64.1	435.3	25.4
9	Combination	305.5	58.3	62.4	426.2	27.0
Population Growth only 50% of the Projected Growth with 50% Retrofit						
10	Indoor conservation	306.4	66.3	66.5	439.2	24.8
11	Landscape conversion	262.7	53.8	54.3	370.7	36.5
12	Combination	247.6	48.7	50.7	347.1	40.6

Effects of Regional Climate Change on Snowpack in Northern Nevada: Research and Education

Basic Information

Title:	Effects of Regional Climate Change on Snowpack in Northern Nevada: Research and Education
Project Number:	2011NV180B
Start Date:	3/1/2011
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	NV02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Hydrology, Water Supply
Descriptors:	Snowpack, Climate Change
Principal Investigators:	Rina Schumer, Anna Knust

Publications

There are no publications.

2013 NIWR Project Update
Effects of regional climate change on snowpack in northern Nevada: Research and education

Rina Schumer Division of Hydrologic Sciences, Desert Research Institute, Reno, NV
Tracy Backes (Master's Student), Desert Research Institute, Reno, NV

Problem

The Truckee River is one of the most highly regulated water bodies in the world, with most of the river water fully allocated to stakeholders including the Department of Interior, State of California, State of Nevada, NV Energy, Pyramid Lake Paiute Tribe, and Truckee-Carson Irrigation District, among others. The distribution of Truckee River water is regulated by an interstate compact and managed by a federal water master.

The Bureau of Reclamation (BOR) currently uses a decision support system (DSS) to manage the Truckee River water system and adhere to the operating agreement in place for the River. Application of the DSS requires a coordinated effort among researchers, operational product designers, and water managers. For example, the Truckee River Riverware operations model is driven by a daily streamflow time series. Currently, a representative time series is selected based on volumetric forecasts from a variety of sources. The Natural Resource Conservation Service (NRCS) uses a model that employs empirical relationships between historical observations of precipitation and streamflow, and also considers the results of physically based precipitation-runoff models developed by the National Weather Service and the Desert Research Institute.

These precipitation-runoff models can also be used to evaluate the impact of climate variations on streamflow in the Truckee River watershed. Water resource managers are increasingly required to incorporate information related to climate in their decisions. Like many watersheds in the Sierra Nevada, it is likely that the first sign of global warming in the Truckee River watershed will be an earlier start to the spring runoff [*Dettinger et al.*, 2004], requiring a modification of reservoir operation on the river. The resultant reduction in streamflow in the late summer directly affects Truckee River water quality issues, as dissolved constituent concentrations increase dramatically under low flow conditions. The Truckee River Operating Agreement Joint Environmental Impact Statement/Environmental Impact Report identified water quality of the Truckee River as a key concern for flow management. As a result, management practices in the basin may require modification based on predicted flows.

Snowmelt accounts for the majority of the annual streamflow in the Sierra Nevada and other mountainous regions. Physically-based precipitation-runoff models in these areas estimate streamflow by deterministic representation of the accumulation and depletion of snowpack. Physical processes, such as sublimation, evaporation, infiltration, and subsurface flow, are combined with an energy balance and a water balance, resulting in streamflow estimates. However, lack of knowledge regarding snow cover remains a significant obstacle in runoff modeling. The uncertainty associated with the spatial and temporal distribution of both precipitation and SWE may lead to errors in the DSS used by BOR for water resource management decisions throughout the runoff season.

Hal Klieforth, a former Desert Research Institute meteorologist, began measuring monthly precipitation and snow water equivalent at 29 sites between Spooner Summit and Henness Pass Junction (Figure 1) in the mid 1960s. Until recently, the majority of these data only existed as hard copies located in Mr. Klieforth's personal office in Bishop, CA. This dataset is unique in its temporal and spatial resolution; measurements were recorded after nearly every storm at sites spanning elevations of 1,400 to 2,590 masl over approximately 24 linear kilometers. Prior to this project, graduate student Hal Voepel organized and began digitization of thousands of precipitation and SWE observations. This research will complete the processing of these data and allow spatio-temporal analysis of regional precipitation patterns in the eastern Sierra Nevada.

Research Objectives

1. Complete QA/QC of a newly obtained data set containing up to 30 years of precipitation and SWE measurements taken after storms events at 29 sites in the Tahoe Basin and Truckee River watershed.

2. Analyze the spatio-temporal statistics of precipitation and SWE from the newly compiled dataset combined with observations recorded by other sources (e.g. Snotel and USGS stream gage sites). As described below, this work has been focused on whether predictable "atmospheric rivers" produce the large snowfall events observed in our storm-event data sets.

Methods

1. During the summer of 2012 we continued processing the storm-level precipitation dataset that Hal Klieforth collected from DRI's mesoscale network of weather stations. Our efforts focused on resolving extreme outliers in the dataset and addressing discrepancies between the transcribed dataset and reports that had been generated based on the original field notes.

2. We explored the contribution of atmospheric river storms to the Tahoe basin's winter precipitation budget. Atmospheric rivers (ARs) are narrow, elongated plumes of concentrated atmospheric vapor flux that act as an extremely efficiently mechanism for transporting moisture to coastal regions. We planned to use precipitation and snow water equivalent data from DRI's mesoscale network to investigate the impact of AR storms east of the Sierra crest. John Mejia's research group at DRI provided an index identifying historical AR landfalls on the Pacific Coast and these dates were cross-referenced with the site visits from our mesoscale precipitation dataset.

   Further investigation revealed that the temporal resolution of this precipitation data was too coarse to allow for a long-term study of AR precipitation. We cross-referenced data from the 11 most frequently visited mesoscale sites with daily precipitation records at National Climatic Data Center (NCDC) cooperative weather stations around the Tahoe Basin. During all of the site visits that covered AR storm dates, we found that 70-90% of these records also included days before or after the AR storm window where non-zero precipitation was recorded at the NCDC coop stations. In other words, for 70-90% of all AR storms we were not able to distinguish how much of the recorded precipitation actually fell during the AR event. In order to avoid overestimating AR storm precipitation, we decided to drop the mesoscale network dataset from our main analysis and focus on the NCDC daily observations. Unfortunately, the NCDC stations have a coarser spatial resolution than the mesoscale network and they do not report snowfall water equivalent.

Principal findings and significance

- This study will benefit scientists and water resources managers in the eastern Sierra Nevada by demonstrating presence or absence of stationarity in the timing and type of precipitation in the region, and whether any changes may be related to changes in regional climate.

- Ongoing analysis using the NCDC daily precipitation dataset is focused on the following questions about cool season precipitation in the Northeastern Sierra Nevada: What atmospheric conditions are most favorable for producing AR precipitation? Does the elevation of the AR moisture plume affect AR precipitation totals? Are there significant differences between AR precipitation east and west of the Sierra crest?

2012/13 Information Transfer Activities

Winter Precipitation Impacts of Midlevel Atmospheric Rivers in the Eastern Sierra Nevada. *T. Backes, R. Schumer, J. Mejia, M. Kaplan, K. Redmond.* Poster presented at Spring 2013 UCOWR meeting, Lake Tahoe, CA.

Student Support

This grant is funding the Master's research of Tracy Backes, a student in the Graduate Program of Hydrologic Sciences at the University of Nevada, Reno.

References

Dettinger, M. D., D. R. Cayan, M. Meyer, and A. E. Jeton (2004), Simulated hydrologic responses to climate variations and change in the Merced, Carson, and American River basins, Sierra Nevada, California, 1900-2099, *Climatic Change*, *62*(1-3), 283-317.

Quantifying the Impact of Hyporheic Exchange on In-Stream Water Quality in the Truckee River, NV

Basic Information

Title:	Quantifying the Impact of Hyporheic Exchange on In-Stream Water Quality in the Truckee River, NV
Project Number:	2011NV181B
Start Date:	3/1/2011
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	NV02
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Models, Water Quality
Descriptors:	Truckee River, Water Quality
Principal Investigators:	Rina Schumer

Publications

There are no publications.

2013 NIWR Project Update
Quantifying the Impact of Hyporheic Exchange on In-Stream Water Quality in the Truckee River, NV

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Zachary Johnson (Doctoral Student), Desert Research Institute, Reno, NV

Problem and Research Objectives

Hyporheic exchange, the mixing of surface water (SW) and groundwater (GW) beneath and adjacent to streams, can have a significant effect on water quality and aquatic habitat (Gooseff et al., 2006). In this zone, stream water residence times are increased which has a large effect on the fate and transport of solutes (Gooseff et al., 2003). Perhaps the most important function for the Truckee River is the removal of nitrogen through denitrification from the system as periphyton growth in the Truckee River is primarily nitrogen limited (Green, 2002). If hyporheic exchange is increased through current restoration efforts, total periphyton biomass should decrease and the minimum nighttime DO concentrations in the river should increase. Understanding the fluctuations of DO in this system are particularly important for the threatened and endangered habitat of the Lahontan cutthroat trout (threatened species) and cui-ui (endangered species) that historically made spawning runs from Pyramid Lake to the Truckee River (US Fish and Wildlife Service 1992, 1995).

Although the physics of hyporheic exchange are well understood, characterization of exchange over long reaches is difficult. For this reason, most hyporheic exchange studies have focused on relatively short reaches ranging from 300 m to 3.5 km (Gooseff et al., 2003; Jones et al., 2008). The proposed reach length on the Truckee River is approximately 56.5 km, stretching between Derby and Marble Bluff Dams. Apart from the challenges posed by the relatively large reach length, few studies have specifically focused on hyporheic exchange in the Truckee River even along short stretches (Knust and Warwick, 2009). We propose to add hyporheic exchange to an existing model which was previously modified for the Truckee River.

Restoration efforts along the Truckee River plan to return the river to more natural conditions including the addition of stream meanders and pool-riffle sequences. Despite the fact that these projects are known to increase hyporheic exchange (Sawyer and Cardenas, 2009), the magnitude of influence towards in-stream water quality does not appear to have been addressed in previous studies. We will use knowledge gained about the hyporheic processes in the Truckee River and the factors controlling them to quantify the relative impact of these restoration efforts on the in-stream water quality.

Specific research objectives for Year 1 were a reactive tracer and nitrogen tracer test in geomorphically distinct sections of the Truckee River to assess whole river and between-reach transient storage characteristics and to develop a framework for including hyporheic exchange in the river water quality model WASP.

Methods

The Year 1 (late summer 2011) dye tracer experiment estimated transient storage (hyporheic and surface storage) parameters for two reaches in the lower Truckee River. The Year 2 (late summer 2012) tracer experiment was carried out in the same two reaches at lower discharge to observe the effect of discharge and geomorphic characteristics of the reaches on transient storage by comparing it to Year 1's results. Nitrate uptake in these reaches was estimated from Year 2's tracer experiment. Uptake will be separated between the main channel and the two transient storage zones in the two reaches. Results were compared between our reaches and previously published data from other stream systems.

A newly developed water quality model is being used to evaluate the effect of transient storage and restoration activity on water quality in the lower Truckee River from Derby Dam to Marble Bluff Dam.

Principal findings and significance

- Surface transient storage dominates hyporheic storage in the "large" Truckee River system. This differs from findings in smaller streams that the hyporheic zone is the dominant transient storage reservoir.
- Two zone storage models more accurately represent Truckee River solute transport processes than a single-zone model. This is important for describing river biogeochemical processing.
- Differences in slope and sinuosity did not have a significant effect on the overall transient storage behavior between the tracer test reaches. Thus detailed geomorphic characterization will not provide increased information for whole-river modelling.
- Increased river discharge significantly reduced the influence of both the surface and hyporheic storage zones on the median transport time in the river.

2012 Information Transfer Activities

Zachary C. Johnson; Rina Schumer; John J. Warwick; Physical and biological N retention in two transient storage zones of the lower Truckee River, NV. 2012 AGU Fall Meeting. San Francisco

A manuscript entitled Two zone transient storage influence on the physical transport of solutes in a large stream by Z. Johnson, J. Warwick, and R. Schumer was submitted to the Journal of Hydrology and is currently under review.

Student Support

This grant is funding the PhD research of Zachary Johnson.

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	4	0	0	0	4
Ph.D.	2	0	0	0	2
Post-Doc.	2	0	0	0	2
Total	12	0	0	0	12

Notable Awards and Achievements

Publications from Prior Years